REMARKS/ARGUMENTS

The Examiner is objecting under 35 U.S.C.§132 to the amendment to the Specification filed September 23, 2003, and rejecting claims 61, 62, 88, and 110 under 35 U.S.C.§112, first paragraph, because there is allegedly no support for the change from "memu" to "emu". The Examiner states that "[w]hile the Examiner acknowledges that the discrepancy in the disclosed Mr, t, and Mr*t values *may* have resulted from the improper use of "memu" versus "emu", the discrepancy would also have resulted from improper numerical values reported for any one of the three variables."

Applicant disagrees. The attached Declaration of Thao Nguyen under 37 CFR § 1.132 provides evidence that it would be clear to one of ordinary skill in the art that the unit alone was the source of the error. As stated in the attached Declaration, one of ordinary skill in the art to which this invention pertains would believe that the stated unit for magnetic remanence, and not the stated numerical range(s) for Mr, t, and/or Mr*t, is incorrect. First, the numerical values stated in the application are 1 x 10^3 less than what one of ordinary skill in the art would expect for the unit memu/cm^3. One of ordinary skill in the art would understand the normal magnetic storage media operating range for magnetic remanence to be from about 100 to 600 emu/cm^3 or 100,000 to 600,000 memu/cm^3. This is quantitatively the same as the numerical range for magnetic remanence as stated in the Specification at pages 14, lines 16-18. Therefore, it would be obvious to one of ordinary skill in the art that the unit and not the numerical range was improper. Second, the units memu/cm^3 are rarely, if ever, used by those of ordinary skill in the art of magnetic storage media to quantify magnetic remanence. Third, one of ordinary skill in the art would understand that the numerical ranges and units for Mr*t and magnetic layer thickness as disclosed at page 14, line 20, to page 15,

line 7, of the Specification are well within the normal operational ranges for these parameters. Finally, if one were to calculate the magnetic remanence using the disclosed ranges for information layer thickness (60 to 300Å) and magnetic moment (or Mr*t) (0.2 to 1.0 memu/cm^2), one would have a value of 333,333 memu/cm^3. The disclosed range for magnetic moment is 100 to 600 memu/cm^3 or 100,000 to 600,000 emu/cm^3. Thus, since one of ordinary skill in the art would recognize the other values to be in the proper ranges, the error in the units for magnetic remanence is further evident from these calculations. Accordingly, one of ordinary skill in the art would understand the error solely to be due to the use of the incorrect units for magnetic remanence.

The Examiner rejects claim 75 under Section 112, second paragraph. The claim has been amended to overcome this rejection.

The Examiner rejects claims 53, 63-64, 66, 68, 75, 78, 82-85, 91-92, 99, 101-102, 126, and 131-133 under 35 U.S.C.§102(b) as being anticipated by Aida et al. (JP 06-215344 A); claims 69-74, 93, 95, and 100 under 35 U.S.C.§103(a) as being unpatentable over Aida et al. and further in view of Moroishi et al.; claims 53-59, 63-64, 66-67, 75, 78, 82-86, 89, 91, 96, 99-102, 106-108, 111, 113, 116-118, 128, and 131-133 under Section 103(a) as being unpatentable over Bloomquist et al. in view of Lal et al.; claims 87, 94, and 109 under Section 103(a) as being unpatentable over Bloomquist et al. in view of Lal et al. and further in view of Aida et al.; claims 61, 88, 95, and 110 Section 103(a) as being unpatentable over Bloomquist et al. in view of Lal et al. and Aida et al. and further in view of Wu et al. (U.S. 6,156,422); claims 60, 90, and 112 under Section 103(a) as being unpatentable over Bloomquist et al. in view of Lal et al. and further in view of JP 05-189738 A (Murata et al.); and claims 65, 97-98, and 114-115 are rejected under Section 103(a) as being

unpatentable over Bloomquist et al. in view of Lal et al. and further in view of U.S. 2002/0114978 to Chang et al.

Applicant respectfully traverses the Examiner's rejections because the cited references fail to teach, individually or collectively, at least the italicized features of the independent claims as follows:

53. A disk for information storage, comprising:
(a) a substrate;
(b) an information layer for containing information; and
(c) an underlayer located between the substrate and the information layer, wherein at least one of the following conditions is true:
(i) *the disk has at least two recording parameters that vary inversely radially outwardly and the underlayer has a thickness that decreases from an inner radial location of the disk to an outer radial location of the disk*; and
(ii) *the information layer has a thickness that increases progressively from an inner disk diameter to an outer disk diameter and the thickness of the information layer at the outermost peripheral information storage location is greater than the thickness of the information layer at the innermost information storage location.*

84. A disk for information storage, comprising:
(a) a substrate; and
(b) an information layer operable to contain information, *wherein (i) the information layer has a first coercivity at a first inner radial location that is more than a second coercivity of the information layer at a second outer radial location and (ii) the information layer has a first magnetic moment at the first inner radial location that is less than a second magnetic moment of the information layer at the second outer radial location.*

106. A disk for information storage, comprising:
(a) a substrate; and
(b) an information layer configured to contain information, wherein a first recording parameter of the information layer at a first radial location is higher than the first recording parameter at a second, different radial location and a second recording parameter of the information layer at the first radial location is lower than the second recording parameter at the second radial location, wherein the first and second first recording parameters are different from one another, and wherein the first recording parameter is coercivity and *the second recording parameter is magnetic moment.*

In a preferred configuration, the present invention is directed to increasing the magnetic remanence and/or the magnetic moment (Mrt) of the disk from the inner disk diameter to the outer disk diameter and decreasing the coercivity from the inner disk diameter to the outer disk diameter. These trends reflect the unique operating conditions in each of the two regions. That is, the higher coercivity and lower magnetic moment in the ID region support a higher linear density due to reduced UBD, and the lower coercivity and higher magnetic moment in the OD region improves writing properties and signal-to-noise radio. The increased Mrt or magnetic remanence in the OD region can provide a higher signal strength (or SNR), thereby permitting more noise to be tolerated and a higher linear bit density (or UBD) to be utilized. The decrease in the coercivity towards the OD region further provides better writing properties in the OD region (in which recording heads typically encounter more resistance to recording or writing bits), thereby providing reduced demands (relative to existing storage media) on the write head, the data detection channel, and the pre-amplifier, and permitting the head to write to the disk at a higher data rate.

<u>Aida et al.</u>

For the convenience of the Examiner, attached to this Amendment and Response is a full translation of Aida et al. The translation different from that questioned by the Examiner in the prior Office Action.

Aida et al. is directed to a magnetic recording medium in which the product of the coercive force and the magnetic film thickness is changed as the head flying height changes radially. As shown in Fig. 2 and ¶¶ 0024-0025, the product value appears to be reduced at the outer periphery of the disk (where flying height is highest) and increased at the inner periphery of the disk (where flying

height is lowest). According to Aida et al., the product is varied by texturing of a P-Ni plating layer to change the center line coarseness R_a so that H_c is greatest at the inner disk radius, varying the thickness of the magnetic film, and changing the crystalline structure of the magnetic film by changing the film thickness of the nonmagnetic Cr undercoat layer. At ¶ 0024, Aida et al. teaches that the coercive force can be increased and decreased by texturing with the degree coarseness of the texturing being related indirectly to the magnitude of the coercivity.

Aida et al. fails to teach (and in fact teaches away from) the increase in the thickness of the magnetic layer from the innermost to the outermost radii, the increase in the magnetic remanence from the inner to the outer radii, and the simultaneous direct variation of both the magnetic layer thickness and under layer thickness as a function of radius. While conceding that Aida et al. fails to teach condition (i) of claim 53 (Office Action at page 6, lines 1-4), the Examiner, in reliance on Figure 1 of the Office Action (which is Figure 7 of Aida et al.) and ¶¶ 0026, 0027, and 0030 of the English Translation, contends that Aida et al. teaches that the information layer has a thickness that increases progressively from an inner disk diameter to an outer disk diameter. Figure 7 does not show the magnetic layer thickness from inner to outer radii but the flying height of the recording head as a function of disk radius (¶ 0030). Due to the arrangement of the head relative to the disk, the flying height is greatest in the central periphery of the disk and lower in the innermost and outermost disk regions. In fact, the experiment from which Fig. 7 was generated implies that the thickness of the magnetic layer is constant from the inner to the outer radii (¶ 0030). Nothwithstanding the foregoing, Aida et al.'s variation of the product of the coercive force and information layer thickness could imply to one of ordinary skill in the art that the magnetic layer

thickness cold be adjusted to be lowest in the high flight region and highest in the adjacent low flight regions (¶0030). However, Aida et al. does not teach that the magnetic layer thickness increases progressively from an inner disk diameter to an outer disk diameter and the thickness of the information layer at the outermost peripheral information storage location is greater than the thickness of the information layer at the innermost information storage location (claim 53).

Bloomquist et al.

Bloomquist et al. fails to overcome the deficiency of of Aida et al. At col. 16, lines 3-42, Bloomquist et al. essentially describes the invention of Aida et al. and states that a coercivity gradient (decreasing from inner to outer peripheries) can be formed "by progressively decreasing the concentration of platinum in the cobalt of the magnetic layer from inner to outer diameters of the disk" and "by varying the thickness of the first sputtered chromium under layer". Bloomquist et al. teaches the use of a magnetic layer of constant thickness. Accordingly, Bloomquist et al. too fails to teach (and in fact appears to teach away from) the increase in the thickness of the magnetic layer from the inner to the outer radii, the increase in the magnetic remanence from the inner to the outer radiis, and the simultaneous variation of both the magnetic layer thickness and under layer thickness as a function of radius.

Lal et al.

Although the Examiner admits that Bloomquist et al. does not teach the simultaneous inverse variation of two recording parameters from the inner to outer disk radii, he states that this combination of features is obvious by combining Bloomquist et al. with Lal et al. Lal et al. is directed to the same problem as Bloomquist et al. but solves the problem in a different way. Lal et

al. addresses the problem of head flying height by using upper and lower magnetic layers. The upper layer has higher coercivity and larger grains while the lower layer has lower coercivity and smaller grains. In the inner peripheral region, where head flying height is lower, the higher coercivity of the upper magnetic layer requires a higher head flux density while in the outer peripheral region the lower coercivity of the lower layer requires a lower head flux (col. 2, lines 56-66). The coercivities of each layer appear to be constant from the inner to outer disk radii (*see* constant thickness underlayers 24 and 52 in Figs. 1 and 3 and col. 9, lines 47-66). The net coercivity of the two layers, however, appears to vary from the inner to the outer disk radii (col. 9, lines 63-66). Contrary to the Examiner's statements, Lal et al. is not clear whether the magnetic remanence increases from the inner to the outer radii (col. 2, lines 44-47 and col. 5, lines 8-12 and Fig. 2) or decreases from the inner to the outer radii (abstract).

Although Lal et al. can be read to teach increasing the magnetic remanence on progressing from the outer to the inner diameter of the disk, Lal et al. fails to teach a similar gradient in the magnetic moment or magnetization-thickness product. The fact that the magnetic remanence has a gradient does not necessarily mean that the magnetic moment has a gradient - let alone a similar gradient. Figure 3 of Lal et al. shows the magnetic layer thicknesses decreasing, and not increasing, from inner to the outer radii. Lal et al. thus teaches the variation of the thicknesses of the magnetic layers in a manner directly opposite to that claimed in certain configurations of the present invention. Whether the magnetic moment of the magnetic media of Lal et al. has a gradient and, if so, whether the gradient increases or decreases from the outer to the inner diameter is determined by which of the opposing gradients in magnetic remanence and sublayer thickness will predominated when

determining the magnetic moment across the radius of the disk. Thus, it is not obvious to one of ordinary skill in the art that providing a gradient in the magnetic moment can provide the benefits of the present invention.

The remaining references, namely Wu et al., Murata et al., Chang et al., and Moroishi et al., fail to overcome the deficiencies of Aida et al., Bloomquist et al., and Lal et al.

The dependent claims provide additional reasons for allowance.

By way of example, dependent Claim 61 provides that the magnetic remanence is one of the recording parameters, the magnetic remanence ranges from about 100 to about 600 emu/cm^3, and a first magnetic remanence at a first inner radial location is no more than about 95% of a second magnetic remanence at a second outer radial location. (See also Claims 87, 109, and 121.)

Dependent Claim 62 provides that the magnetic moment is one of the recording parameters, the magnetic moment ranges from about 100 to about 600 emu/cm^3, and a first magnetic moment at a first inner radial location is no more than about 95% of a second magnetic moment at a second outer radial location. (See also Claim 94.)

Dependent Claim 69 provides that the thickness of the information layer ranges from about 60 to about 300 angstroms and the information layer has a first thickness at a first inner radial location and a second thickness at a second outer radial location and the first thickness is at least about 75% of the second thickness. (See also Claim 92.)

Dependent Claim 70 provides that the information layer includes a first magnetic layer, a second magnetic layer, and an at least substantially non-magnetic layer located between the first and

second magnetic layers and a thickness of at least one of the first and second magnetic layers increases from the inner diameter to the outer diameter.

Dependent Claim 77 provides that a bit length in an outer diameter region is greater than a bit length in an inner diameter region. (See also Claim 85.)

Dependent Claim 82 provides that the information layer has a first areal density at a first inner radial location and a second areal density at a second outer radial location and the first areal density is at least about 105% of the second areal density. (See also Claims 83 and 101.)

Applicant has added new dependent Claims 134-136, which provide additional reasons for allowance. Independent claim 134 is a combination of allowable dependent claim 127, intervening dependent claims 126 and 127, and independent claim 53. Independent claim 135 is a combination of allowable dependent claim 129, intervening dependent claims 91 and 92, and independent claim 84. Accordingly, the newly added claims are allowable.

It is submitted that the application is now in form for allowance. Therefore, early notification of same is respectfully requested. The Examiner is invited to contact the undersigned by telephone if doing so would assist in the resolution of this case.

Respectfully submitted,

SHERIDAN ROSS P.C.

By: Douglas Swartz

Douglas W. Swartz
Registration No. 37,739
1560 Broadway, Suite 1200
Denver, Colorado 80202-5141
(303) 863-9700

Date: April 16, 2004

J:\3123\-297\amend.02.wpd

APPENDIX

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:	Group Art Unit: 1773
LIN and NGUYEN	Examiner: Kevin M. Bernatz
Serial No.: 10/052,621	DECLARATION OF THAO NGUYEN UNDER 37 CFR § 1.132
Filed: January 17, 2002	
Atty. File No.: 3123-297	
For: "STORAGE MEDIA WITH NON-UNIFORM PROPERTIES"	

"EXPRESS MAIL" MAILING LABEL NUMBER: EV316803609250US
DATE OF DEPOSIT: 4-16-2004

I HEREBY CERTIFY THAT THIS WITH THE UNITED STATES POSTAL SERVICE "EXPRESS MAIL POST OFFICE TO ADDRESSEE" SERVICE UNDER 37 C.F.R. 1.10 ON THE DATE INDICATED ABOVE AND IS ADDRESSED TO THE ASSISTANT COMMISSIONER FOR PATENTS, WASHINGTON, D.C. 20231.

TYPED OR PRINTED NAME: Amy Duarte

SIGNATURE: Amy Duarte

Commissioner for Patents
P.O. Box
Alexandria, VA 22313-1450

Dear Sir:

I, Thao Nguyen, being over the age of eighteen, declare as follows:

1. I am the Vice President of Advanced Technology and Heads/Media at Maxtor Corporation, a position I have held since April of 2002. Previous to that position, I have held other senior positions at Maxtor Corporation, since joining Maxtor Corporation in 1998. I am a co-inventor of the above-referenced patent application which is assigned to Maxtor Corporation. I receive compensation from Maxtor.

2. I received a B.A. in Mathematics and Physics from Boston College in 1981, and was elected to *Phi Beta Kappa*. I received my Ph.D in Materials Science and Engineering from the Massachusetts Institute of Technology in 1987. From 1987 until present, I have worked in the field of head/disk interface technologies, recording materials, recording media and heads. I am a co-author of 15 scientific papers. I have been awarded at least seventeen (17) U.S. patents,

and have numerous patent applications on file, for various aspects of subjects related to disk and recording technology. I subscribe to and analyze various magazines and journals, which discuss advances in the art of head/disk interface technologies, materials science, and storage media.

3. As noted previously, I am a co-inventor of the above-referenced patent application and familiar with the application. This Declaration is being submitted in connection with patent prosecution activities for the above-referenced patent application.

4. My education, research and work history, at a minimum, qualify me as one of ordinary skill in the art of storage media.

5. The following statements in Paragraphs 6 through 8 are made with reference to the level of ordinary skill in the art at the time of filing of the patent application, namely January 17, 2002.

6. In an Amendment and Response mailed September 23, 2003, Applicants amended both the Specification and certain claims to change the recited magnetic remanence range from "about 100 to about 600 memu/cm^3" to "about 100 to about 600 emu/cm^3. In the Examiner's December 16, 2003 Office Action, the Examiner rejected the amendment contending that Applicants' amendment introduced new matter. While the Examiner acknowledged that the discrepancy in the disclosed Mr, t, and Mr*t values may have resulted from the improper use of "memu" versus "emu," the discrepancy allegedly could also have resulted from improper numerical values reported for any one of the three variables. More specifically, the Examiner stated that there is no evidence that the error necessarily resulted from mistaken units, and only the mistaken units.

7. As a person of ordinary skill in the art to which this invention pertains, I believe that it would be obvious to one of ordinary skill in the art that the stated unit for magnetic

remanence, and not the stated numerical range(s) for Mr, t, and/or Mr*t, is incorrect. First, the numerical values stated in the application are 1 x 10^3 less than what one of ordinary skill in the art would expect for the unit memu/cm^3. In my experience, the normal magnetic storage media operating range for magnetic remanence is about 100 to 600 emu/cm^3 or 100,000 to 600,000 memu/cm^3. This is quantitatively the same as the numerical range for magnetic remanence as stated in the Specification at pages 14, lines 16-18. Therefore, it is obvious to me and would be obvious to one of ordinary skill in the art that the unit and not the numerical range was improper. Second, the units memu/cm^3 are rarely, if ever, used by those of ordinary skill in the art of magnetic storage media to quantify magnetic remanence. Third, one of ordinary skill in the art would understand that the numerical ranges and units for Mr*t and magnetic layer thickness as disclosed at page 14, line 20, to page 15, line 7, of the Specification are well within the normal operational ranges for these parameters. Accordingly, one of ordinary skill in the art would understand the error solely to be due to the use of the incorrect units for magnetic remanence.

8. For these and other reasons, I submit that the amendment to the specification, changing memu/cm^3 to emu/cm^3, does not add new matter to the specification because one of ordinary skill in the art would have understood the units to be properly emu/cm^3 and not memu/cm^3.

9. I hereby declare that all statements made herein of my own are true and all statements made on information and belief are believed to be true; and further, that the statements were made with the knowledge that willful false statements and the like, if so made, are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the subject application or any patent issuing thereon.

Date: April, 15, 2004 By: Thao Nguyen

Thao Nguyen

J:\3123\-297\1-132decNguyen rev 2.doc

Japanese Laid-Open Patent Publication No. 6-215344
Publication Date: August 5, 1994
Application No.: 5-3527
Date of Application: January 12, 1993
Applicant: Kabushiki Kaisha Hitachi Seisakusho
Inventor: Kazuhiro Nakao et al.
Title of the Invention: MAGNETIC RECORDING MEDIUM

[SCOPE OF THE CLAIMS]

[CLAIM 1] A magnetic recording medium for forming a magnetic recording film on a nonmagnetic base, the magnetic recording medium being characterized by a decrease of the product of the thickness of the magnetic recording film and the coercive force on the inner surface of the magnetic recording film in the region in which the flying height of the magnetic recording head increases.

[CLAIM 2] A magnetic recording medium for forming a magnetic recording film on a nonmagnetic base, the magnetic recording medium being characterized by having a recording region which decreases the minimum value of the product of the thickness of the magnetic recording film and the coercive force on the inner surface of the magnetic recording film 5% or more relative to the maximum value of this of this product at the inner surface.

[CLAIM 3] The magnetic recording medium of Claims 1 and 2, wherein a nonmagnetic intermediate layer is formed between the nonmagnetic base and the magnetic recording film.

[CLAIM 4] The magnetic recording medium of any one of the Claims 1 through 3, wherein the magnetic recording film comprises multiple film layers mediated by nonmagnetic film.

[CLAIM 5] The magnetic recording medium of any one of the Claims 1 through 4, wherein the product of the thickness of the magnetic recording film and the coercive force of the

magnetic recording film is adjusted by a texturing process so as to change the average coarseness of the center line on the inner surface on the nonmagnetic base.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[FIELD OF INDUSTRIAL APPLICATION] The present invention relates to a magnetic recording medium such as a magnetic disk used in a magnetic disk device or the like, and particularly relates to a magnetic recording medium having superior overwriting (overwrite) characteristics in high-density recording, i.e., a magnetic recording medium with a high erasure rate of old records by overwriting.

[0002]

[DESCRIPTION OF THE RELATED ART] Conventional magnetic recording media used for high-density recording are known to realize high-density recording by obtaining a high coercive force using CoCrPt or CoPtTa magnetic recording film, for example, as disclosed in Japanese Laid-Open Patent Publication No. S59-88806, and using CoNiCrTa magnetic film, for example, as disclosed in Japanese Patent No. H1-237925. It is further known that a high coercive force has been obtained and high-density recording has been realized through a manufacturing method of spattering a CoNiCr magnetic film on a Cr undercoat film while applying a bias voltage of 0 to 300 V to the base, as described in, for example, the Japan Society of Applied Magnetics Conference Proceedings published in November 1989 (page 13).

[0003]

[PROBLEMS TO BE SOLVED BY THE INVENTION] In the aforesaid conventional art, although there have been various studies of the magnetic recording media used for high-density recording using as high a coercive force as possible,

these investigations have concerned systems for magnetic recording regeneration devices and none of them considered overwrite characteristics, nor have there been attempts at basic improvement of conventional overwrite characteristics. In particular, the current situation is that the overwrite characteristics necessary for magnetic disks are determined experientially. The overwrite characteristics are evaluated by the overwrite characteristics (1) or (2) described below, but in both cases the overwrite characteristics are considered better the lower the erasure residue rate.

[0004] In the conventional art, when data are overwritten while the magnetic recording head moves over the magnetic recording medium, there is minimum recording magnetic intensity applied to the magnetic recording film of the magnetic recording medium in the region where the head is flying at its greatest height and, therefore, the old signals are difficult to erase and new signals are difficult to record, such that the overwrite characteristics are at their worst. In coated-type magnetic recording media, since overwrite characteristics are good in the region where the head flies at the greatest height, consideration has been given to using methods such as reducing the thickness of the magnetic recording film believed to be related to overwrite characteristics; however, overwrite characteristics are not necessarily sufficiently improved due to the high coercive force in magnetic recording media used for high-density recording. Furthermore, in magnetic recording media manufacturing methods using vacuum technology, such as vacuum deposition, spattering and the like, although these methods may be suitable due to the increased coercive force produced by making the magnetic recording film thinner, the overwrite characteristics may also be adversely affected.

[0005] Accordingly, an object of the present invention is to provide a magnetic recording medium that eliminates the previously described problems associated with the conventional art, and is suited for high-density recording and has superior overwrite characteristics in the entire recording region independent of the change in height of the flying head in each recording region in the radial direction and the like.

[0006]

[MEANS FOR SOLVING THE PROBLEM] These objects are attained by the magnetic recording medium of the present invention which introduces the concept of the product of the thickness of the magnetic recording film and the coercive force on the inner surface of the magnetic recording film as a factor determining the overwrite characteristics of the magnetic recording medium that is constructed as described below using this concept.

[0007] (1) In a magnetic recording medium consisting of a magnetic recording film on a nonmagnetic base, the magnetic recording medium is characterized by decreasing the product of the thickness of the magnetic recording film and the coercive force on the inner surface of the magnetic recording film in the region in which the flying height of the magnetic recording head increases. Accordingly, this product is a minimum at the highest flying position (recording region) of the magnetic recording head, and a maximum at the lowest flying position (recording region) of the magnetic recording head. In this case, a nonmagnetic protective film may be provided on the magnetic recording film as necessary, and a lubricating film may be formed inside the nonmagnetic protective film, or on the nonmagnetic protective film, or inside and on the nonmagnetic protective film.

[0008] (2) Furthermore, when considering the height of the flying magnetic recording head in each region of the magnetic recording medium, the magnetic recording medium consisting of a magnetic recording film on a nonmagnetic base is characterized by having a recording region (record track) which decreases the minimum value of the product of the thickness of the magnetic recording film and the coercive force on the inner surface of the magnetic recording film 5% or more (and desirably 10% or more) relative to the maximum value of this of this product at the inner surface.

[0009] (3) From the perspective of improving recording regeneration characteristics, a nonmagnetic intermediate film is formed between the magnetic recording film and the nonmagnetic base.

[0010] (4) Further, the magnetic recording film may be formed of multiple layers of film of at least two or more layers mediated by nonmagnetic film.

[0011] (5) Still further, the product of the thickness of the magnetic recording film and the coercive force of the magnetic recording film is adjusted by performing a texturing process so as to change the center line average coarseness on the inner surface on the nonmagnetic base.

[0012]

[OPERATION] The operation is described based on the previously mentioned construction.

[0013] The overwrite characteristics of typical magnetic recording media, such as magnetic disks and the like, are adversely affected the greater the coercive force of the magnetic recording film and the higher the flying height of the magnetic recording head. Furthermore, these characteristics become worse the greater the thickness of

the magnetic recording film under the same coercive force and the same flying height.

[0014] (1) According to the present invention, the concept of the product of the coercive force and the thickness of the magnetic recording film is introduced among the magnetostatic characteristics of the magnetic recording medium, and the characteristics of the magnetic recording medium are stipulated by this product; since this product decreases in the recording range where the height of the flying head is greatest, the overwrite characteristics become nearly uniform in the entire recording range of the magnetic recording medium even when the flying height of the magnetic recording head changes via the recording region (track position) in the radial direction and the like of the magnetic recording medium, and excellent overwrite characteristics are obtained.

[0015] (2) Specifically, improvement of the overwrite characteristics of the magnetic recording medium can be accomplished by having a track region that decreases the minimum value of the product of the magnetic recording film and the coercive force of the inner surface of the magnetic recording film (the product value at the highest flying position) 5% or more, and desirably 10% or more, relative to the maximum value of the product at the inner surface (the product value at the lowest flying position) in accordance with the flying height of the magnetic head in each recording track region. In the magnetic recording medium, a nonmagnetic protective film is provided on the magnetic recording film as necessary, and a lubricating film is formed inside the nonmagnetic protective film, or on the nonmagnetic protective film, or both inside and on the nonmagnetic protective film, an arrangement that is particularly effective in improving overwriting

characteristics when the effective flying height from the magnetic recording film to the magnetic recording head element is not fixed at the inner surface of the magnetic recording medium.

[0016] (3) Furthermore, from the perspective of improving record regeneration characteristics, a nonmagnetic intermediate film (undercoat film) is provided between the magnetic recording film and the nonmagnetic base, the magnetic characteristics of the magnetic recording film are controlled by adjusting the thickness of this nonmagnetic intermediate film so as to attain a suitable high-density recording and obtain a magnetic recording medium having excellent overwrite characteristics, and which has excellent characteristics for both recording and regeneration.

[0017] (4) Furthermore, the magnetic characteristics of the magnetic recording medium suited for high-density recording can be controlled by the magnetic recording film having a multilayer film structure of at least two or more layers mediated by nonmagnetic film, so as to obtain a magnetic recording medium better suited for high-density recording.

[0018] (5) Moreover, the magnetostatic characteristics, such as the coercive force of the magnetic recording film, can be adjusted in the entire recording region in the radial direction of the magnetic recording medium by performing a texturing process to change the center line average coarseness Ra on the inner surface of the nonmagnetic base, for example, by performing a texturing process to maximize the center line average coarseness Ra at the position requiring a maximum product value (the position of the minimum flying height), so as to obtain even more excellent overwrite characteristics.

[0019] The center line average coarseness is the average value of the height of the peaks relative to the average center line based on the average of the intermediate heights of the peaks and valleys of the concavo-convex surface.

[0020]

[EXAMPLES] The examples of the present invention are described in detail below based on the drawings.

[0021] Fig. 1 is a cross-sectional view of the disk-like magnetic recording medium of an example of the present invention. In the drawing, reference number 11 refers to a substrate formed of Al alloy, reference number 12 refers to a nonmagnetic plating film formed of Ni-P, Ni-Cu-P or the like, reference number 13 refers to a nonmagnetic undercoat film formed of Cr or the like, reference number 14 refers to a magnetic film formed of Co base alloy, reference number 16 refers to a nonmagnetic protective film formed of C or the like, and reference number 17 refers to a lubricating film formed of perfluoroalkylpolyether or the like. Among these, the nonmagnetic undercoat film 13, magnetic recording film 14, and nonmagnetic protective film 16 are all formed by spattering, and the lubricating film 17 is formed by an application coating method or the like. The detailed structure and manufacturing method of the magnetic recording medium are described below.

[0022] First, the first example is described. A substrate, formed by an Al alloy base 11 having an external diameter of 130 mmϕ, internal diameter of 40 mmϕ, and thickness of 1.9 mm on which is formed a 20 μm thick nonmagnetic 11 wt% P-Ni plating layer, is subjected to surface polishing, and the surface is provided with 10 nm micro gouges at centerline coarseness Ra uniformly in the circumferential direction (like concentric circles) of the

substrate. Thereafter, micro gouges are again provided so as have 5 nm micro gouges at centerline coarseness Ra in the circumferential direction (like concentric circles) from radial position 45 mm to 65 mm; on a nonmagnetic plating layer 12 having a thickness of 13 μm is formed a Cr undercoat film 13 of 100 nm at a substrate temperature of 200°C, Ar pressure of 7 mTorr, DC input power of 4 W/cm2, over which is formed a magnetic recording film 14 using CoCr14Ta6 alloy to form a 60 nm thick film under Ar pressure of 7 mTorr, and DC input power of 4 W/cm2.

[0023] Furthermore, as a reference sample, a magnetic recording medium is formed which has 10 nm micro gouges of the centerline coarseness Ra uniformly in the substrate circumference direction on the surface.

[0024] Fig. 2, shows the results of the magnetostatic characteristics of 7x7 mm samples of the prepared media sectioned at 35 mm and 55 mm, and measured by vibration sample magnetometer (VSM) with a saturated magnetic field of 10 kOe and 20 min/loop measurement time. In the radial position 55 mm sample, the coercive force Hc was 1000 (Oe) relative to the coercive force Hc of 1100 (Oe) of the radial position 35 mm sample. Furthermore, in the reference sample the coercive force Hc was 1100 (Oe) at both radial positions 35 mm and 55mm. In general, as the magnetic characteristics of the magnetic film, the coercive force Hc is reduced and increased by performing a texturing process, and in the present example a processing method was used to reduce the coercive force Hc as the texturing process coarseness decreased. (Conversely, a method may be used to increase the coercive force Hc as the texturing process coarseness decreases.)

[0025] When record regeneration characteristics of these disks were measured by a thin-film head gap length

of 0.4 μm having the flying curve shown in Fig. 3, the result was an increase in peripheral speed and flying height to the degree of increase in the radius of the magnetic recording medium in both the reference sample and sample (example), as shown in Fig. 4; the output amplitude increased since the head-to-magnetic recording medium relative speed was increased by the increase in peripheral speed regardless of the increase in spacing loss.

[0026] The overwrite characteristics of the present invention are measured as described below. Among the modulation methods used in magnetic recording devices, overwriting is performed at the shortest record wavelength after writing to the magnetic recording medium at the longest record wavelength. The ratio of the erasure residue (record label) of the longest record wavelength after the overwrite at this time and the record label of the longest record wavelength before this overwrite expressed in decibels is designated overwrite characteristic (1). Furthermore, the ratio of the erasure residue (record label) of the longest record wavelength after this overwrite and the written part of the overwritten shortest record wavelength expressed in decibels is designated overwrite characteristic (2). Overwrite characteristic (1) has been reported in the present example, but a similar result was found for overwrite characteristic (2). This time, as shown in Fig. 4, the overwrite characteristic degraded and matched the flying curve (the increase in flying height) in the reference sample. However, as shown in the same drawing, on the exterior periphery side from the radial position 45 mm in the test sample (example) there was a 3 dB improvement over the reference sample. In the case of the example, this is thought to have been produced by the coercive force being lower at the exterior periphery side compared to the

interior periphery side even though the film thickness is identical. This time, the product of the coercive force and the thickness of the magnetic recording film was 66 (Oeμm) for the reference sample, while it was 66 (Oeμm) on the inner periphery and 60 (Oeμm) on the exterior periphery of the test sample. That is, the overwrite characteristics of the combination of the head and medium of the example were improved to the degree that the product was reduced by the relationship of 0.5 dB/Oeμm. Since this relationship value is dependent on the magnetic head used, it cannot stipulate a universal numerical value. However, the reduction of the product value above is well suited as an excellent value of overwrite characteristics.

[0027] A second example is described below. A substrate, formed by an Al alloy base 11 having an external diameter of 130 mmϕ, internal diameter of 40 mmϕ, and thickness of 1.9 mm on which is formed a 20 μm thick nonmagnetic 11 wt% P-Ni plating layer, is subjected to surface polishing, and the surface is provided with 10 nm micro gouges at centerline coarseness Ra uniformly in the circumferential direction of the substrate; on a nonmagnetic plating layer 12 having a thickness of 13 μm is formed a Cr undercoat film 13 of 100 nm at a substrate temperature of 200°C, Ar pressure of 7 mTorr, DC input power of 4 W/cm2, over which is formed a magnetic recording film 14 using CoCr14Ta6 alloy to form a 40 nm film under Ar pressure of 7 mTorr, and DC input power of 4 W/cm2. Thereafter, using a mask, a 20 nm magnetic recording film 14 is formed using CoCr14Ta6 alloy from the radial position 25 mm to 45 mm at Ar pressure of 7 mTorr, and DC input power of 4 W/cm2. This time the magnetostatic characteristics were 110 (Oe) at radial position 35 mm (magnetic film thickness of 60 nm),

and 1200 (Oe) at radial position 55 mm (magnetic film thickness of 40 nm). When record regeneration characteristics were measured by a thin-film head gap length of 0.4 μm having the flying curve shown in Fig. 3, the output amplitude was increased by the increase in peripheral speed, the output decreased at the radial position (radial position of 45 mm or more) having variable film thickness (film thinning), although the output amplitude increased at the innermost radial position regardless of the increase in spacing loss, for both the reference sample and the test sample (example), as shown in Fig. 5.

[0028] The overwrite characteristic degraded and matched the flying curve in the reference sample. However, on the exterior periphery side from the radial position 45 mm in the test sample (example) there was a 5 dB improvement over the reference sample. This time, the product of the coercive force and the thickness of the magnetic recording film was 66 (Oeμm) for the reference sample, while it was 66 (Oeμm) at radial position 25 to 45 mm and 48 (Oeμm) at radial position 45 to 65 mm of the test sample. The overwrite characteristics can be set at excellent values by changing film thickness and coercive force and changing the product of the two.

[0029] A third example is described below. Fig. 6 shows the overwrite characteristics relative to a standardized value of the product value (the product value at the radial position of least flying height, for example, the innermost peripheral position, is designated the maximum value of 1.0), when the film thickness was gradually varied to change the product of the coercive force and film thickness relative to a product value of the film thickness and coercive force of 66 (Oeμm); when the rate of change in the decrease of the product value was less than 5% at the radial position of

highest flying height, there was no observed improvement in overwrite characteristics; therefore, it is clear that a rate of change in the decrease of 5% or more, and desirably 10% or more, is required.

[0030] A fourth example is described below. In this example, a magnetic recording head having the flying curve shown in Fig. 7 was used, and the flying height was maximized at the intermediate area and minimized at the innermost periphery and outermost periphery areas in the radial direction of the disk recording medium. This flying characteristic was obtained by positioning the magnetic head at an inclination relative to the rotational direction of the magnetic disk recording medium, mainly using a relatively small disk less than 5 inches ϕ. Relative to this magnetic recording head, the medium was to be divided into three regions of a high flight region (radial position 42 to 53 mm), and low flight regions (radial positions 30 to 42 mm, and 53 to 64 mm), such that the product value of the coercive force and film thickness in the high flight region would be lower than the product value in the low flight regions. Therefore, a centerline average coarseness Ra of 4 nm was formed in the radial position 42 to 53 mm, and an Ra of 8 nm was formed in the other regions by forming micro gouges on the Ni-P substrate. Thereafter, a Cr undercoat film of 50 nm was formed at a substrate temperature of 200°C, Ar pressure of 7 mTorr, and DC input power of 4 W/cm2, and over this was formed a 50 nm magnetic recording film 14 using CoCr14Ta6 alloy at Ar pressure 7 mTorr and Dc input power of 4 W/cm2. The magnetostatic characteristics this time were 1200 (Oeμm) at the radial position 42 to 53 mm, and 1400 (Oeμm) in the other regions, that is, the product values were 60 (Oeμm) and 70 (Oeμm), respectively. The overwrite characteristic this time was 70 (Oeμm) overall for

both the test sample and reference sample shown in Fig. 8. The overwrite characteristics show a trend similar to the change in flying height in the reference sample, there was improvement in the high flight region (radial position 42 to 53 mm) in the test sample, with the advantage being 4 dB.

[0031] By considering the use of these manufacturing methods and the flight of the head, it is possible to obtain record regeneration characteristics which are excellent for overwriting even in the case of high-density recordings by means of a combination of the coercive force and magnetic recording film thickness.

[0032] A vertical type magnetic recording medium (fifth example) is described below. When considering magnetic recording media used for vertical magnetic recording, the magnetic recording film thickness must be increased compared to media used for inner surface magnetic recording. Furthermore, the coercive force must be considered in terms of the vertical component in the perpendicular direction relative to the surface, but the overwrite characteristics can be controlled by the product of the coercive force and the magnetic recording film thickness. Since the effective flying height of the head does not change compared to magnetic recording devices of the type which there is normally contact of the head with the medium, it is unnecessary to change the product of the coercive force and magnetic recording film thickness; however, in noncontact type magnetic disk devices, the technique of changing the product of the coercive force and the magnetic recording film thickness is effective for improving the overwrite characteristics.

[0033] An example (sixth example) of an inner surface magnetic recording medium is described again below based on Fig. 9.

[0034] A substrate, formed by an Al alloy base 91 having an external diameter of 130 mm ϕ, internal diameter of 40 mm ϕ, and thickness of 1.9 mm on which is formed a 20 μm thick nonmagnetic 11 wt% P-Ni plating layer, is subjected to surface polishing, and the surface is provided with 10 nm micro gouges at centerline coarseness Ra uniformly on the surface from radial position 45 to 64 mm, then, on a nonmagnetic plating layer 92 having a thickness of 13 μm is formed a Cr undercoat film 93 of 50 nm at a substrate temperature of 200°C, Ar pressure of 7 mTorr, DC input power of 4 W/cm2, over which is formed a magnetic recording film 94 using CoCr14Pt6 alloy to form a 20 nm thick film under Ar pressure of 7 mTorr, and DC input power of 4 W/cm2. Thereafter, a Cr intermediate layer 95 having a thickness of 2 nm is formed at Ar pressure 7 mTorr and DC input power of 4 W/cm2, and finally a magnetic recording film 94 having a thickness of 20 nm is formed using CoCr14Pt6 at Ar pressure 7 mTorr and DC input power of 4 W/cm2. The magnetostatic characteristics this time were 1500 (Oe) at radial position 35 mm, and 1300 (Oe) at radial position 55 mm. When record regeneration characteristics were measured by a thin-film head gap length of 0.4 μm having the flying curve shown in Fig. 3, in both the reference sample and the test sample (example), the output amplitude was increased by the increase in peripheral speed, and the output amplitude was greater than at the innermost peripheral position regardless of the increase in spacing loss, as shown in Fig. 10.

[0035] This time, the overwrite characteristic for the reference sample was 60 (Oeμm) on the entire surface of both the using the product of the coercive force and the total magnetic recording film thickness, as shown together in Fig. 11. The overwrite characteristics showed a trend identical

to the change in the flying height in the reference sample, but there was improvement in the high flight height region (radial position 45+ mm) in the example, and an advantage of approximately 4 dB. That is, even in multilayer magnetic recording films, the characteristics of the magnetic recording film is expressed by the product of the coercive force and the total magnetic recording film thickness, and the overwrite characteristics can be improved by changing this product value at the inner surface of the medium.

[036] Furthermore, although a method of controlling the coercive force of the magnetic film by changing the center line coarseness Ra via concentric circle-like micro gouges on the substrate, and a method of changing the magnetic recording film thickness have been mentioned as examples of methods of changing the product of the coercive force and magnetic recording film thickness, another method concerns controlling the coercive force by changing the crystalline array structure of the magnetic film formed on the nonmagnetic undercoat layer by changing the film thickness of the nonmagnetic undercoat layer (Cr film thickness) on the inner surface thereof (even at a fixed magnetic film thickness, even with a fixed magnetic film thickness, the coercive force of the magnetic film increases to the degree the nonmagnetic undercoat film is thickened, and the coercive force of the magnetic film decreases to the degree the nonmagnetic film is thinned), and it is possible to change the product of the coercive force and the magnetic recording film thickness by changing the centerline average coarseness Ra in accordance with the radial position by a crossed micro gouging process (for example, a method of adding texture in a inclined direction at various slopes in directions intermediate to the radial direction and circumferential direction).

[0037] Furthermore, although the method of spattering has been mentioned among vacuum techniques as a manufacturing method, it is unnecessary to limit the method to this manufacturing method, inasmuch as vacuum deposition, ion beam spattering, plating, and coating application methods are also good methods for forming a magnetic recording film having a magnetic particle structure.

[0038] The material used as the substrate is not limited only to a plating on an Al alloy, inasmuch as a glass substrate, and nonmagnetic substrate of Tl and Mg alloy also may be used.

[0039] Although the substrate has only been described as having a diameter of 5.25 inches (130 mm), the present invention is not dependent on the diameter of the substrate and is applicable to substrates having various diameters.

[0040] Moreover, the nonmagnetic undercoat film and the nonmagnetic intermediate film are not limited to C, and may be composed of Cr alloy, and W and No nonmagnetic metals and the like.

[0041] According to the present invention as described in detail above, since the structure is such that the product of the coercive force on the inner surface of the magnetic recording film and the thickness of the magnetic recording film decreases to the degree that the magnetic head moves to the high flight region, the over write characteristics can be made nearly constant in all recording regions of the magnetic recording medium even though the flying height of the magnetic head differs depending on the recording region, thereby producing the effect of excellent overwrite characteristics.

[0042] Furthermore, since the value of the coercive force can be easily adjusted to a desired value in the entirety of the recording region in the radial direction of

the magnetic recording medium by performing a texturing process on the nonmagnetic substrate so as to change the centerline average coarseness on the inner surface, the achieved effect is to easily obtain a magnetic recording medium having excellent overwrite characteristics over the entirety of the recording region.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1] is a cross-sectional view of a magnetic recording medium according to a preferred embodiment of the present invention;

[Fig. 2] is diagram showing the magnetostatic characteristics of the magnetic recording medium;

[Fig. 3] is a chart showing the flight path curve of the magnetic recording head measuring the record regeneration characteristics of the magnetic recording medium;

[Fig. 4] is a chart showing the results of the measured record regeneration characteristics of the magnetic recording medium;

[Fig. 5] is a chart showing the results of the measured record regeneration characteristics of a magnetic recording medium according to a further embodiment of the present invention;

[Fig. 6] is a chart showing the relationships among the overwrite characteristics and standardized value of the product of the magnetic recording film thickness and the coercive force of a magnetic recording medium according to a further embodiment of the present invention;

[Fig. 7] is a chart showing the flight track curve of the magnetic recording head measuring the record regeneration characteristics of a magnetic recording medium according to a further embodiment of the present invention;

[Fig. 8] is a chart showing the results of measuring the record regeneration characteristics of a magnetic recording medium according to a further embodiment of the present invention;

[Fig. 9] is a cross-sectional view of a magnetic recording medium according to a further embodiment of the present invention;

[Fig. 10] is a chart showing the results of the output amplitude of is a chart showing the results of the measured record regeneration characteristics of a magnetic recording medium according to a further embodiment of the present invention; and

[Fig. 11] is a chart showing the results of the overwrite characteristics of a magnetic recording medium according to a further embodiment of the present invention.

[DESCRIPTION OF REFERENCE SYMBOLS]

11, 91 Substrate
12, 92 Nonmagnetic plating film
13, 93 Nonmagnetic undercoat film (intermediate layer)
14, 94 Magnetic recording film
95, Nonmagnetic film inserted between magnetic recording films
16, 96 Nonmagnetic protective film
17, 97 Lubricating film

れば、磁気記録膜の面内の保磁力と磁気記録膜厚との積を、磁気ヘッド浮上量が高い記録領域に行く程減少させるように構成したので、磁気ヘッド浮上量が記録領域によって異なっていても、重ね書き特性は、磁気記録媒体の全記録領域でほぼ一定とすることができ、良好な重ね書き特性が得られるという効果を奏する。

【0042】また、非磁性基体に、中心線平均粗さが面内で変化するようにテクスチャ加工を施すことにより、磁気記録媒体の半径方向の全記録領域において、保磁力の値を所望値に容易に調整することができるので、全記録領域に対し良好な重ね書き特性を有する磁気記録媒体が容易に得られるという効果を奏する。

【図面の簡単な説明】

【図1】本発明の一実施例の磁気記録媒体の断面図である。

【図2】本発明の一実施例の磁気記録媒体の静磁気特性結果を示す図である。

【図3】本発明の一実施例の磁気記録媒体の記録再生特性を測定した磁気記録ヘッドの浮上軌跡曲線を示す図である。

【図4】本発明の一実施例の磁気記録媒体の記録再生特性を測定した結果を示す図である。

【図5】本発明の他の実施例の磁気記録媒体の記録再生特性を測定した結果を示す図である。

【図6】本発明の他の実施例の磁気記録媒体の保磁力と磁気記録膜厚の積の規格化値と重ね書き特性との関係を示す図である。

【図7】本発明の他の実施例の磁気記録媒体の記録再生特性を測定した磁気記録ヘッドの浮上軌跡曲線を示す図である。

【図8】本発明のさらに他の実施例の磁気記録媒体の記録再生特性を測定した結果を示す図である。

【図9】本発明のさらに他の実施例の磁気記録媒体の断面図である。

【図10】本発明のさらに他の実施例の磁気記録媒体の出力振幅の結果を示す図である。

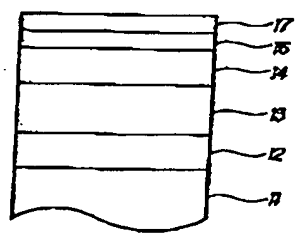
【図11】本発明のさらに他の実施例の磁気記録媒体の重ね書き特性の結果を示す図である。

【符号の説明】

11，91 基板
12，92 非磁性めっき膜
13，93 非磁性下地膜（中間層）
14，94 磁気記録膜
95 磁気記録膜間挿入非磁性膜
16，96 非磁性被覆膜
17，97 潤滑膜

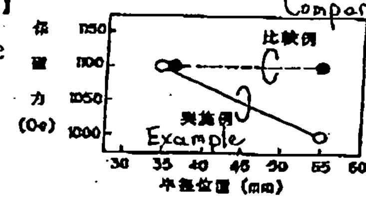
【図1】 Fig. 1

【図1】



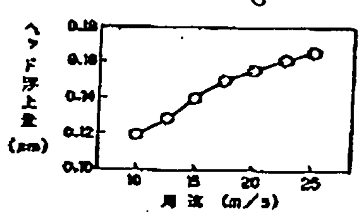
【図2】 Fig. 2

【図2】



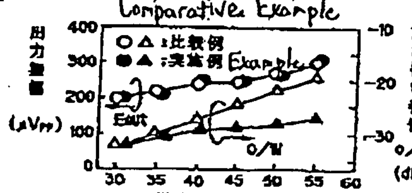
【図3】 Fig. 3

【図3】



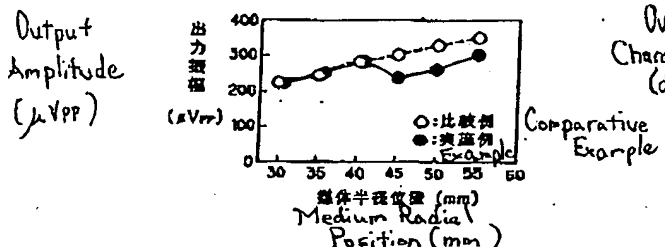
【図4】 Fig. 4

【図4】



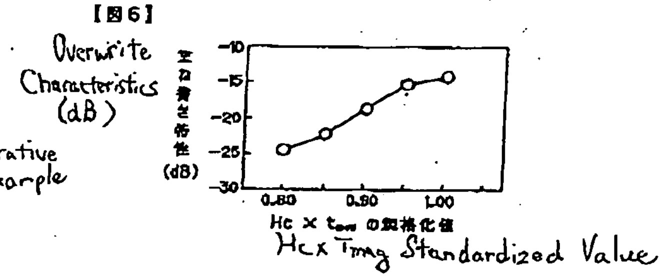
【図5】 Fig. 5

【図5】



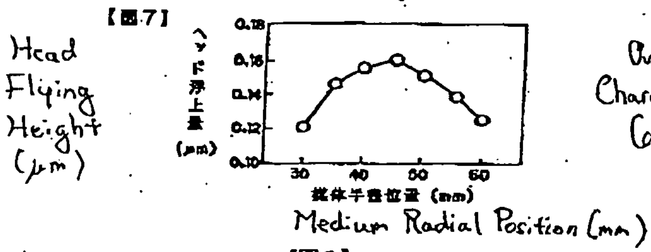
【図6】 Fig. 6

【図6】



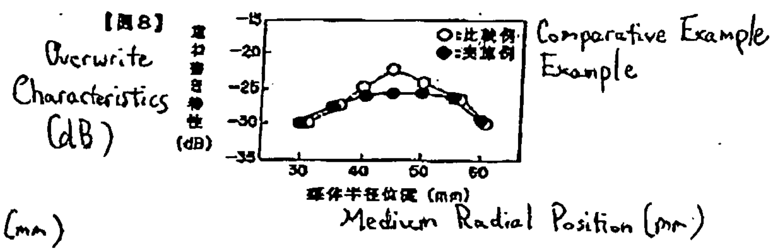
【図7】 Fig. 7

【図7】



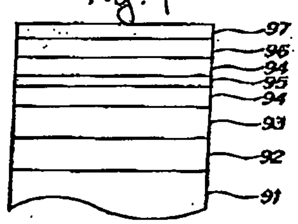
【図8】 Fig. 8

【図8】



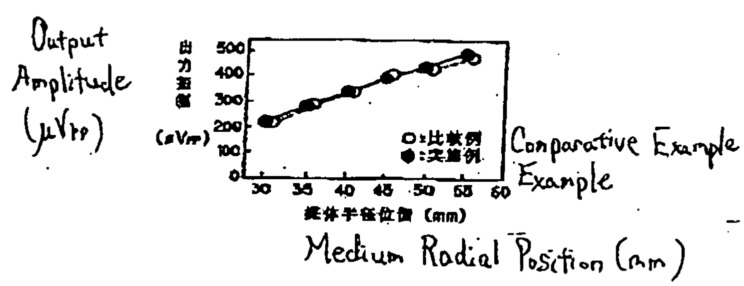
【図9】 Fig. 9

【図9】



【図10】 Fig. 10

【図10】



【図11】 Fig. 11

【図11】